A cohort study of one-year functional and radiographic outcomes following intra-articular distal radius fractures

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Abstract

Background The purpose of this study was to describe the outcomes of a series of patients followed prospectively after intra-articular distal radius fractures.

Methods One hundred forty-eight patients with intra-articular fractures (mean age, 47 years; age range, 44–54 years; gender distribution, 60 males and 88 females) were treated with cast only, arthroscopy/closed reduction plus pins, arthroscopy/closed reduction with external fixation, open reduction and internal fixation (ORIF) alone, and ORIF with external fixation according to surgeon preference and fracture characteristics. The 1-year outcomes across the groups were measured radiographically ($n=148$) and functionally ($n=113$; 1-year Wrist Outcome Measure score, Grip Strength, SF-36, and PRWE scores).

On February 1, 2013, Dr. Jim Roth, renowned hand surgeon and founding partner of the Hand and Upper Limb Centre, passed away.

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Results Radiographically, the groups had statistically significant differences in radial inclination, volar tilt, intra-articular step-off, and radial shortening in the pre-treatment X-rays. However, following treatment, treatment groups demonstrated no difference statistically in their follow-up radiographic measures. One-year PRWE scores were found to be statistically different across groups. Across groups, the ORIF-alone treatment group had the highest PRWE score reflecting greatest amount of pain and disability. One-year wrist outcome measure scores and grip strength scores were also found to be significantly different across treatment groups. The general health status as measured by the SF-36 was not found to be different across treatment groups.

Conclusions These findings are consistent with treatment by indication; suboptimal ORIF outcomes may reflect older practice patterns with dorsal plating. A randomized control trial that compares treatments controlling for fracture severity and studies that develop formal clinical prediction rules for treatment assignment are needed.

Keywords Distal radius · Intra-articular · Fracture · Treatment · Radiograph · Patient-reported outcomes · Impairments

Introduction

Distal radius fractures are among the most common orthopaedic injury, accounting for one-sixth of all fractures [19] and often result from a fall on an outstretched hand with the wrist in hyperextension. A number of classification systems have been used to describe the type and severity of fractures [5]. Amongst these, displaced intra-articular distal radius fractures are considered more severe and are more likely to have complications [18] and poor outcomes [20].

Despite the high frequency of distal radius fractures, treatment options following a distal radius fracture are varied. Three

separate Cochrane reviews examined fracture management including the use of external fixation (9 trials, 510 participants), comparing external fixation and conservative treatment (15 trials, 1,022 participants), and percutaneous pinning (13 trials, 940 participants). These concluded that there is currently insufficient evidence to define when reduction is indicated and what type of fracture fixation should be used [8–10].

Benefits for different treatment approaches to fracture fixation have been proposed. Open reduction and internal fixation permits early mobilization which may confer an advantage in terms of functional outcome. In recent years, volar plating has replaced dorsal plating as the treatment of choice though evidence to support this is weak and just now emerging. External fixation operates through ligamentotaxis and results in less soft tissue stripping and no retained hardware. The fixator is purported to neutralize the compressive forces across a joint, preventing collapse of the fracture during the initial 2 to 4 weeks of healing when bone resorption and early new-bone formation are maximal [23]. Arthroscopy can be used in combination with other methods of fixation to allow for better visualization of ligaments and articular surface without soft tissue damage usually occurring in open reduction and internal fixation (ORIF) [23]. However, the effectiveness of these different forms of treatment is poorly understood. Randomized trials of all treatment options for different subgroups of fracture would be required to develop a fully evidence-based treatment algorithm and are not yet available in the published literature. As a preliminary step, it can be useful to compare how outcomes vary in routine practice. The purpose of this observational study was to describe impairment, functional outcome and radiographic alignment, and general health status following various treatment groups in a non-randomized cohort treated for intra-articular fractures.

Materials and Methods

Patients were consecutively recruited from the Hand and Upper Limb Centre (HULC) following an intra-articular distal radius fracture between 2003 and 2008. Initially, all of these fractures were treated with closed reduction in the emergency room. The reason for referral was two attempts at closed reduction or an intra-articular step-off on X-ray. Surgery was carried out by HULC physicians according to their personal indications and contraindications. There was no attempt to influence or standardize treatment choices. All of the surgeons at the Hand and Upper Limb Centre are fellowship trained surgeons. Hand therapy services were available to all patients, and the referral and subsequent therapy management were decided on a case-by-case basis based on need. Informed consent was obtained from all patients for being included in this study. All procedures followed were in accordance with the ethical standards of the responsible committee on human

experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Functional Outcome and Impairment Measures

Patients were re-evaluated at 1 year (± 2 weeks). Evaluations included self-reported wrist pain/disability (Patient Rated Wrist Evaluation) [14, 17] and physical and mental health status (Short Form-36) [22]. Flexion, extension, radial deviation, ulnar deviation, pronation, and supination were measured using the NK computerized goniometer using standardized landmarks and protocols that have demonstrated reliability. Grip strength was measured bilaterally and scored with the NK digit-grip which provides reliable static grip strength scores. They were expressed as a percentage of the other side with a correction for hand dominance (7 %). A checkers dexterity test from the Jebson's Dexterity test was also performed [12]. A summation of total wrist outcome measure (WOM) was constructed [15] using the grip strength, range of motion (wrist flexion/extension [13]), wrist rotation (pronation/supination) [2], and ulnar and radial deviation, and an ordinal measure of composite finger flexion.

Radiographic Measures

The pre-treatment and follow-up films of each patient were reviewed. Pre-treatment films were those films which were acquired at the Hand and Upper Limb Centre prior to being treated. They therefore reflect the extent of the fracture and surrounding soft tissue damage. All measurements were performed by one orthopaedic resident (VR) according to a standardized data collection process following training from a hand surgeon. Direct measures of alignment taken from radiographs have previously been shown to have excellent reliability (radial inclination, dorsal angulation, and radial shortening (ICC 0.76–0.77) [16]. The films were also classified according to the McMurtry classification systems which classifies intra-articular fractures (having a fracture that extends into the radiocarpal or radioulnar joint and is displaced 1–2 mm) based on the number of fractured parts indicating the severity of the fracture and amount of comminution [5]. In this classification system, the definition of a "part" is a piece of bone that can be internally stabilized and is functionally significant. A two-part fracture describes an intra-articular fracture that is present in either the lunate or scaphoid facets. A three-part fracture describes a fracture that separates both the lunate and scaphoid facets as well as presents with a transverse fracture that separates the radius proximally and distally. A four-part fracture describes a three-part fracture with the addition of a fracture which separates the lunate facet into volar and dorsal regions. A five-part fracture describes an intra-articular fracture which presents with a high degree of comminution which can exist in

Table 1 McMurtry classification of distal radius fractures

	Cash only	Artho/closed reduction plus pins	Artho/closed reduction plus external fixation	Open reduction/internal fixation	Open reduction/internal fixation plus external fixation	Total
Two parts	21	6	3	9	6	45
Three parts	24	7	9	3	5	48
Four parts	8	5	2	3	5	23
Five or more parts	6	3	11	5	7	32
Total	59	21	25	20	23	148

The severity of fractures according to the McMurtry Classification of distal radius fracture is indicated by the number of parts of the fracture

a variety of fracture patterns [5]. Volar tilt, radial inclination, radial shortening, and articular step-off were measured for all of the films using a goniometer.

Statistical Analysis

A one-way analysis of variance (ANOVA) was performed for each measurement (WOM, grip strength, PRWE, SF-36) comparing all different treatment groups. Statistical significance was set at $p < 0.05$. The primary outcomes measure was the total PRWE score. For the radiographic data, descriptive statistics were calculated for all dependent variables. A one-way (ANOVA) was performed for each radiographic measurement comparing all different treatment groups. Statistical significance was set at $p < 0.05$.

Results

In this study, 148 consecutive patients treated between displaced intra-articular distal radius fractures were treated at the Hand and Upper Limb Centre. These patients had an

average age of 47 years, an age range of 44–54 years, and 60 were male and 88 female. Radiographic outcomes were collected on all participants ($n = 148$); however, 35 declined to return for follow-up assessment, leaving absent data for the remaining clinical outcome measures ($n = 113$).

In total, approximately 38 % of patients were treated conservatively while 33 % of patients underwent arthroscopy/closed reduction plus either external fixation or pins and 29 % underwent ORIF with/out external fixation. The comparability of the subgroups with regards to severity of fracture is shown in Table 1. The closed reduction group had 14 patients; the arthroscopy/closed plus pins group had 8; the arthroscopy/closed plus ex-fix group had 13; the ORIF group had 8, and finally, the ORIF plus ex-fix group had 12. All fracture groups were represented in each treatment group, although a trend for less comminuted fractures to be treated more conservatively was observed (cast only, $n = 21$ ‘two-parts’, $n = 24$ ‘three parts’). A chi-squared test of independence determined that fracture treatment group and McMurtry classification is related ($p = 0.034$).

One-year PRWE scores were found to be statistically different across groups ($p = 0.027$) (Table 2). There was however a trend for 1-year PRWE scores to be higher as the treatment became more complex with the highest PRWE score being found in the ORIF treatment group reflecting the greatest amount of pain and disability. One-year WOM scores were also found to be significantly different across treatment groups ($p = 0.005$). There was a trend for 1-year WOM scores to be higher in the cast-only treatment group, which is also reflected in the grip strength scores ($p = 0.039$). No significant differences were found across treatment groups comparing 1-year SF-36 scores.

Individual one-way analyses of variance between each treatment conditions were performed for each separate radiographic measure. In the pre-treatment X-rays, the results of this study found significant differences across the five treatment groups for each individual radiographic measure (intra-articular step-off ($p = 0.007$), volar tilt ($p = 0.002$), radial shortening ($p = 0.001$), and radial inclination ($p = 0.001$)). The amount of intra-articular step-off was greater with more intensive treatments (cast to ORIF

Table 2 Outcomes versus treatment type

	Cash only	Artho/closed reduction plus pins	Artho/closed reduction plus external fixation	Open reduction/internal fixation	Open reduction/internal fixation plus external fixation
1-year WOM score	26.4±2.3	26.9±2.0	25.1±2.7	24.2±2.9	24.5±3.2
1-year grip strength score	34.4±5.3	34.3±6.0	31.5±4.3	28.7±8.4	32.5±8.0
1-year SF-36 score	48.4±11.6	51.2±6.8	51.2±7.0	44.9±11.1	49.0±10.1
1-year PRWE score	11.5±15.7	14.0±10.6	17.4±17.6	32.0±28.1	20.1±28.2
Number of participants	59	21	25	20	23

Mean values for each outcome measure are shown for each fracture type with the standard deviation shown in parenthesis

Fig. 1 Radiographic measures of intra-articular step-off ($n=148$, values are mean $\pm$ standard deviation). Intra-articular step-off measurements (millimeters) before and after treatment for all treatment modalities

plus external fixation) as shown in Fig. 1. Similarly, there was a tendency for increased amounts of pre-reduction volar tilt and radial shortening with more invasive treatment options, as shown in Figs. 2 and 3, respectively. There were statistical differences across groups with respect to pre-treatment radial inclination ($p=0.001$). The cast only group had an average pre-treatment radial inclination of $20.7\pm6.4^\circ$ and therefore had the least compromise

in radial inclination (normal average value of approx. 23° [4]) whereas the arthroscopy/closed reduction plus external fixation group had an average pre-treatment radial inclination of $9.3\pm10.0^\circ$ thereby having the greatest deviation from the normal amount of radial inclination (Fig. 4). There were no statistical differences in radiological outcomes across treatment groups in the follow-up measures of radiographic alignment (intra-articular

Fig. 2 Radiographic measures of radial shortening ($n=148$, values are mean $\pm$ standard deviation). Radial shortening measurements (millimeters) before and after treatment for all treatment modalities

Fig. 3 Radiographic measures of radial inclination ($n=148$, values are mean $\pm$ standard deviation). Radial Inclination measurements (degree sign) before and after treatment for all treatment modalities

step-off, volar tilt, radial shortening, and radial inclination) (Figs. 1, 2, 3, and 4).

Discussion

This study of treatment selection and related outcomes indicates that surgeons select more invasive treatments for more complex or more displaced fractures. One-year treatment

outcomes varied across treatment groups and were most favorable for the cast group, which reflected that the surgeon's assignment of treatment was based on fracture severity and also that the cast group had more a favorable prognosis.

The primary outcome in this study was PRWE scores that reflect pain and function. A PRWE value of less than 25 was used as cut-off for acceptable function. Based on this criterion, the ORIF group had suboptimal PRWE scores (32.0 ± 28.1). Since this cohort took time to assemble, a substantial number

Fig. 4 Radiographic measures of volar tilt ($n=148$, values are mean $\pm$ standard deviation). Volar tilt measurements (degree sign) before and after treatment for all treatment modalities

had dorsal plating, and this likely contributed to suboptimal outcomes in this group as we have illustrated in a previous trial [7]. Dorsal plating has been associated with higher rates of complications, carpal collapse, and a reduced range of motion [21]. The results of this current study verify that poor outcomes are associated with dorsal plating of the distal radius, although a direct comparison with volar plating was not conducted. Furthermore, ORIF patients had more severe fractures as indicated by radiographic displacement at baseline. In this current study, all other groups had an acceptable PRWE score (<25), suggesting that, despite more severe fracture patterns, the treatment by indication approach was able to achieve positive outcomes.

Based on the observational results of this study, there was a tendency of better motion, grip strength, and reduced pain and disability of the wrist with less invasive interventions. The data suggest that there was a gradient along these treatment modalities with reference to treatment selection (Table 2). This trend agrees with a study done by Doi et al., who reported that arthroscopic reduction provided better functional outcome than ORIF [3]. The rationale behind the arthroscopic approach is that it provides a better outcome due to the ability to visualize ligaments and the articular surface without soft tissue damage that is incurred during ORIF treatment. Thus, this previous study suggested that the arthroscopic method produces a better anatomic reduction and decreased operative scarring which resulted in a better outcome. This is similar to the observations on group difference in this current study, although our groups were not comparable at baseline. An observational study such as this is not able to differentiate treatment effectiveness but can provide evidence about areas where suboptimal outcomes occur and is useful to identify potential differences in outcomes that should be investigated by use of a randomized trial.

The general health status as measured by the SF-36 was not found to be different across treatment groups. Comparative normative data in the Canadian population in the age range relevant to this study (45–54) have a mean value of 51.3 and 51.4 for the physical and mental component summary scales, respectively [11]. Therefore, health status was not different in these patients with distal radius fractures than in the normal population. This suggests that a DRF had a minimal long-term effect on health status. However, the SF-36 however is not a responsive measure in the distal radius fracture population [20], so it is possible that important health effects were missed by this measure.

Another goal of treatment in addition to improving pain/disability and function is to achieve anatomical reduction that is accurate in terms of articular congruity and which is maintained throughout the duration of follow-up and beyond [8, 17, 18, 21]. Normative data for each radiographic measure have been established as well as amounts of acceptable reduction and alignment. The American Society for Surgery of the Hand has created guidelines to define overall levels of acceptable alignment and have considered dorsal angulation $>10^\circ$, radial

inclination $<15^\circ$, and ulnar positive variance (radial shortening) ≥ 3 mm to be considered unacceptable alignment. Descriptive statistics in our current study comparing radiographic measures of alignment indicate that, on average, acceptable amounts of dorsal angulation and radial shortening were achieved following treatment. Additionally, the intra-articular step-off has been shown to be closely correlated to the occurrence of post-traumatic arthritis with a step of greater than 1 mm giving osteoarthritis [1, 6]. However, in our study, all patients had good reduction with follow-up intra-articular step-off less than 2 mm. Therefore, we expect the incidence of post-traumatic arthritis to be very low. Based on the results of this study, it appears as though patients received the appropriate treatment option as statistical differences in radiographic alignment were found before treatment and not following treatment.

This observational cohort suggests that it appears as though patients received the appropriate treatment option as statistical differences in radiographic alignment were found before treatment and not following treatment. The decisions made in selection of fracture fixation were able to ameliorate the disadvantage of a more serious injury with the exception of ORIF which we attribute to the use of dorsal plating in this cohort. Due to the lack of randomization and small subgroup sizes, a randomized control trial comparing these different treatment options is necessary to provide more definitive evidence.

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Conflict of Interest Emily A. Lalonde declares that she has no conflict of interest.

Ruby Grewal declares that she has no conflict of interest.

Vaishnav Rajgopal declares that he has no conflict of interest.

James Roth has no conflict of interest.

Joy C. MacDermid declares that she has no conflict of interest.

Statement of Human and Animal Rights The research protocol received institutional approval prior to commencing the study. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent Letters of Information were given to each participant prior to enrollment in the study, and informed consent was obtained for all participants enrolled in this research study.

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